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BIOGEOCENOTIC APPROACH TO THE EVALUATION OF THE CONDITION OF FOREST ECOSYSTEMS UNDER ANTHROPOGENIC INFLUENCE*

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Abstract. Many-sided complex evaluation is given of the condition of forest biogeocenoses located in the vicinity of industrial works, by chemical and biological parameters. The biological aspect is the most informative for the understanding of various disturbances unavoidable in natural communities under conditions of anthropogenic stress. The principle parameters of the vegetational conditions at the north and south subzones of taiga have on the whole a general trend to decrease toward the discharge center. By comparison of the principal characters some distinctions typical for forests of different latitudinal situation are revealed.

Keywords: Forest biogeocenoses–anthropogenic stress–natural communities

Introduction

The modern stage of research on the evaluation of the quality of natural objects is characterized by a great body of accumulated data regarding the changes in the various components of ecosystems under anthropogenic influence. As there is a great variety of techniques for data collection, the results are incomparable and thus quantitative comparison cannot be made. Based on complex studies on vegetation, animal communities, soil, litter, waters, the problem of degradation of natural systems as a whole has been outlined by studies of forest biogeocenoses in regions of metallurgical works.

As biocenotic parameters had to be compared for biocenoses at different distances from the source of discharges the studies were performed in phytocenoses of the same types in identical ecotopes. Studies were performed in the north taiga in fruticulose-green moss spruce forest and fruticulose-green moss pine forest formed on humic-illuvial podzol and situated at the middle and upper parts of upland slopes; in the south taiga in mixed grass birch forests formed at the place of the former pine woods, and in mixed grass pine forests. The

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mesophytic variety of these phytocenoses was also studied, attributing to the steep slopes of ridges by brown mountain forest soil.

The metallurgical works selected as the study objects have some advantages for the evaluation of the consequences of influence of their discharges at the adjacent territory: 1. the degree of disturbance of biocenoses is determined at a comparatively small territory, the forested surface well adsorbing aerosols; 2. the studied natural communities are within the zone of insignificant impact of nearby industrial objects, so the impact zone of the studied local pollution source can be well differentiated; 3. in both cases the complete range of biogeocenoses by the degree of disturbance is represented, including territories with completely degraded vegetation and organogenic soil horizon to areas having no apparent deviations by structural and functional parameters.

Sample plots were situated on transects crossing the center of discharges, along and across the predominant wind direction. The control plots were selected reliably outside the zone of discharges of works.

The prolonged and highly toxic pollution with sulfur-containing oxides and heavy metals present in the discharges of metallurgical works is a potent impact factor for natural communities, directly and indirectly influencing the structural and functional interconnection of all components of a biogeocenosis, and essentially suppressing their vital activities. The principal parameters of the condition of vegetation at the north and south subzone of taiga showed

Table 1

Changes in main parameters of the north taiga forest phytocenoses at different distances from the discharge source

Parameters	Distance from discharge source, km									
	70	30	20	10	5	2	5	10	20	70
	spurce forests						pine forests			
Area of cross section of trees, m^2/ha	25.4	6.5	5.6	4.0	3.6	1.5	0.1	2.8	11.8	22.1
Timber stock, m^3/ha	91.4	36.7	34.0	21.0	17.2	2.5	0.3	10.9	89.8	115.1
Vital condition of trees, points	2.0	3.5	3.5	4.5	4.5	5.0	4.5	4.0	2.5	2.0
Grass-shrublets and moss-lichen stratum										
Number of species	26	22	16	8	3	6	5	20	31	30
Above-ground phytomass, 100 kg/ha	62.0	43.8	32.7	24.0	9.9	19.1	22.4	21.9	37.3	80.0
Total projection coverage, %	146.5	80.6	69.5	32.5	21.0	16.8	26.9	41.9	87.5	120.0
Similarity quotient, %	100	62.5	47.6	35.3	31.0	25.0	24.2	54.2	78.0	100
Depth of litter layer A_0, cm	12.5	13.0	10.0	7.2	7.7	4.5	8.0	8.0	11.0	9.0

on the whole a general trend to decrease towards the discharge center. By the comparison of the principal characters some distinctions were revealed, typical for forests of different latitudinal situations.

The species diversity is an important index of the disturbance of the structure of a plant community. In both cases the decrease in the species diversity of phytocenoses was observed towards the discharge source (Tables 1, 2). This tendency was especially noticeable in the south taiga communities with their high floristic abundance.

By anthropogenic impact the species diversity does not always regularly decrease towards the predominance of species more adapted to the modified environmental conditions due to potential changes in species composition, and in the present case the similarity quotient was more informative, obtained by comparison of the species composition of vegetation at the disturbed territories and control plot. In the zone of maximum pollution the pine forests of the north taiga differed more from the controls than the pine forests of the south taiga (Table 1, 2).

The condition of the arboreal stratum determined mainly by the composition of edificators is essential for the stability of phytocenosis. The south Urals have a long history of diverse commercial activities. In areas of concentrated chopping, if such a factor as chemical pollution is superimposed, only the active pioneer species possessing a wide ecological range can survive. Therefore, in the south taiga the intensive succession from conifer forests to

Table 2

Changes in main parameters of the south taiga forest phytocenoses at different distances from the discharge source

Parameters	Distance from discharge source, km						
	30	12	8	5	3	30	5
	birch forests				pine forests		
Age of tree stand, years	70	80	45	50	45	80	80
Area of cross section of trunks, m^2/ha	20.0	23.7	14.1	18.4	14.2	65.0	17.0
Timber stock, m^3/ha	134.0	189.4	98.8	119.0	70.0	433.6	112.0
Vital condition of tree stand, points	1.5	2.0	2.5	3.5	3.5	2.5	4.0
Number of species in phytocenosis	79	62	38	25	8	73	29
Grass stratum							
Above-ground phytomass, 100 kg/ha	7.6	7.1	3.4	1.1	0.3	5.6	0.8
Total projection coverage, %	80	75	33	18	2.3	60	2.5
Similarity quotient, %	100	37.5	26.9	19.6	10.5	100	33.0
Depth of litter, cm	2.0	3.2	1.5	2.0	3.4	3.0	1.8
Stock of litter, 100 kg/ha	190.0	190.0	163.0	228.0	276.0	210.0	190.0

small-leaved forests (mainly birch forests) was recorded. The areas of pine forest that had conserved were found to have limited distribution.

The data on trunk numbers and areas of cross section did not support the supposed trend to decrease by the pollution gradient. The decrease in the timber stock in the high pollution zone can be explained by the decrease in the age of the arboreal stands at the territories adjacent to the works. The radial growth of wood did not decrease. Pine is more sensitive to pollution. According to our data, in the impact zone 20% of the trees perished, the remaining pines having much thinner crowns with dry tops, yellowed needles with much shorter life term. The birch growth was common in the young growth of pine phytocenoses which points out to successions of regressive type leading to substitution of the birch forest for the pine forest.

In the north taiga the forests are mainly formed of pine and spruce. In the impact zone the coniferous species disappeared almost completely. The young growth of both pine and spruce was, however, more stable. The same was true for the deciduous trees. According to our data the vegetation term of the latter was shortened by 1 month on the average, being a reaction of adaptation to the high pollution of the environment. The census of the number of trees on the plots removed from the source of discharge by 70 (the control), 30, 20, 10, 5, 2 km revealed drastic decrease in the number of living spruce trees by the pollution gradient: 416, 296, 203, 116, 32, 0 ind./ha. The same was recorded for the pine forests. Approaching the discharge source the ratio of the wood stock of living trees to that of dead trees changed as follows: 8.0, 5.5, 0.9, 2.0, 0.7, 0.2. The growth of trunk wood in the most polluted zone decreased by 4 times compared to the control. No such regularity was observed for the birch. In the impact zone under conditions of lessened root competition, on the opposite, it grew intensively; the number of living trunks surpassing the number of dry trunks by several times.

Thus, in both cases a similar situation of change of the initial indigenous plant associations into secondary, derivative ones was observable. In the south version this process was more intensive, the secondary birch forests rapidly and lastingly occupying all habitats disturbed by man. In the north taiga this process was much slower, besides this, birch regrowth did not always substitute the coniferous forest due to deep and unreversible soil transformations.

The phytomass is one of the most important structural parameters characterizing the condition of a plant community. Our determinations of phytomass of the lowest strata of the phytocenosis revealed sharp decrease in both cases with the approach to the works (Tables 1, 2). In the north plots the values of this parameter were found to be much higher at all points of transects than in the south plots, as the weight of the whole above-ground part was recorded including perennial shoots of shrublets and mosses, the lat-

ter constituting about half of the total phytomass stock in the soil cover of plant communities of the north taiga under the control conditions. The total projection coverage of plants, on the whole correlating with changes in phytomass, also showed a decrease approaching the works.

The litter stock characterizes two reciprocal processes: the size of fall-off and the rate of its decomposition. The violation of this sensitive balance causes the predominance of one process or a complete inhibition of both. Thus in the south taiga birch forests within 5—8 km radius, the biomass gain was sharply decreased and the process of decomposition predominated, while in the near zone of 2—5 km the process of decomposition was rather completely suppressed and litter (mainly the fall-off of leaves and trees of the birch) accumulated in large quantities on the surface reaching in some cases the depth of its layer up to 18 cm. In the north taiga version litter accumulated quite differently. Under conditions of high humidity the thick litter layer (up to 12 cm) mainly consisted of moss remains, decreasing in dept while turning into peat. This process was due to an increasing pollution level, regularly decreasing towards the discharge center (Tables 1, 2). In both cases the soil was completely washed off the slopes at the territories immediately adjacent to the discharge source, contributing to the intensive development of the erosion processes.

The disturbance of the differentation of plant communities into strata is a qualitative structural parameter of changes in phytocenoses, including vegetation of the lowest strata. This parameter was more expressive for the south taiga phytocenoses having more complex vertical structure. Thus in the mixed grass birch forests the grass cover of 4 strata was gradually changed; the high grass (5–8 km from the works) and low-growing grasses (2–5 km from the works) changed into birch forests with dead litter. In the north taiga spruce and pine forests, already at early stages (beginning with 20 km from the works) mosses and lichens were eliminating and the two-strata grass-shrublet and moss-lichen cover was changed into a much disturbed stratum of grasses *(Deschampsia flexuosa)* and shrublets *(Empetrum hermaphroditum)*.

On the whole, the north taiga phytocenoses are less stable to pollution as they have low species diversity, more simple structure, low productivity and capacity of biological turnover, and consequently possess lower capacity for regeneration.

Simultaneous studies on the changes in animal and plant populations are necessary for the understanding of the system of degradation of biocenoses under human impacts. Table 3 shows the reaction of the soil mesofauna by its main parameters to the increase of soil pollution with the approach to an industrial object in the shrublets-green moss spruce forests.

The behavioural studies on vertebrate animals demonstrated that some groups of species possessing good properties as indicators react differently to

Table 3

Changes in main parameters of soil mesofauna in the shrublets-green moss spruce forests (Murmansk region)*

Parameters	Distances from the discharge source, km					
	70	30	20	10	5	2
Biomass g/m²	5742	1920	851	450	335	108
Numbers ind./m²	412	318	184	22	22	8
Group diversity	14	12	10	6	2	3

*Determined by A. L. Tikhomirova

changes in environmental conditions. Recording of the distribution of these groups demonstrated that in the south taiga birch forests the shrew occurs not closer than 4–6 km to the discharge source, vole — 6–8 km, mole — 10–16 km (determined by O. F. Sadykov).

On sample plots of transects in the vicinity of both metallurgical works soil sections were made, soil samples for heavy metal content were taken, soil acidity, humus content and microbiological activity were determined. It was found that in the impact zone the content of heavy metals in the upper soil horizons surpasses that of the background by 1–2 orders of magnitude, the soil acidity is increased, the organic carbon content decreased, and the microbiological activity dropped by many times.

Trace element contents were determined in water samples taken from small standing waters in the proximity of sample plots, in rain and snow, in the period prior to the spring snow melting. The water samples were treated by express filtration through lavsan filters by vacuum under field conditions. Such a method of water treatment excludes any losses of heavy metal compounds occurring in the process of their resorption and absorption on vessel walls during transportation (method and techniques of filtration are designed by A. M. Stepanov).

Studying the process of regeneration of forest forming species on soils of different pollution degree an experiment was arranged for the germination of spurce and pine seeds. For each species four experimental variants were compared. The greatest difference was observed for the germs in the extreme variant of the experiment 3 months after planting. The main growth parameters of germs of pine and spruce on soil taken at different distances from the metallurgical works are shown in Table 4.

Thus, a many-sided complex evaluation of the condition of forest biogeocenoses located in the vicinity of industrial works, by chemical and biological parameters is presented. The biological aspect is the most informative for the understanding of various disturbances unavoidable in natural communities under conditions of anthropogenic stress.

Table 4

Main growth parameters of germs of pine and spruce grown during pot experiment in soil taken at different distances from the metallurgical works

Parameters (spruce / pine)	Distance from the discharge source, km			
	30	20	10	2
Total length of germs, cm	11.30 18.40	10.22 16.53	5.43 14.07	3.45 6.10
Length of root system, cm	7.90 12.70	6.77 11.07	1.89 8.70	0.30 2.10
Average weight of a germ, mg fresh weight	90.00 143.20	64.50 119.00	38.70 153.20	15.5 50.00
% germination	53 91	55 94	60 82	45 82